Important Principles found in Nature

and successful ideas

Mach's Principle

- All measurable quantities are definable only in relation to other measurable quantities

Principle of Relativity

- Physical theory must be expressible in a form that is unchanged by a change in frame of reference

Causality

- Present events should be determinable by past events alone
- With relativity: Space-like separated events cannot influence each other
- With quantum theory, transition amplitudes have analyticity

Localizability

- There exist in nature non-trivial systems which can be isolated, i.e. described to some approximation without the inclusion of the dynamics of systems elsewhere.

Uniqueness of Natural Observations

- There exists a local function of the configurations of an isolatable system, such that the observed configurations are near the maximum of that function.

  (The function is called the ‘action’.)

Emmy Nöether's Theorem

- For every continuous symmetry of the action for a system, there will be an additively-conserved quantity with a corresponding current.

Conserved Quantities

- “External” space-time symmetries give energy-momentum conservation and angular momentum conservation
- “Internal” symmetries give electric charge, baryonic charge, leptonic charge conservation, ...
- “Continuity” of events in time follows from conservation laws

Fundamental Interactions follow a Gauge Symmetry

- Relativity and Quantum Theory mean particles and fields must carry spin 0, 1/2, 1, 3/2, etc. of Planck's constant.
- Between identical particles, spin 0 and 2 exchanged bosons cause an attractive force, while spin 1causes a repulsive force.
- Short-range interactions are carried by a 'gauge' field, i.e. a spin 1 exchanged between the interacting pair.

Half interger spin particles carry additively conserved quantities

- Electric Charge
- Baryonic Charge
- Leptonic Charge
- Strangeness
- Charm
- Topness
- Bottomness
- etc.

Observation affects what is and will be observed

- Heisenberg's Uncertainty Principle
- Observables
- Nature not 'there', but rather possibilities evolve

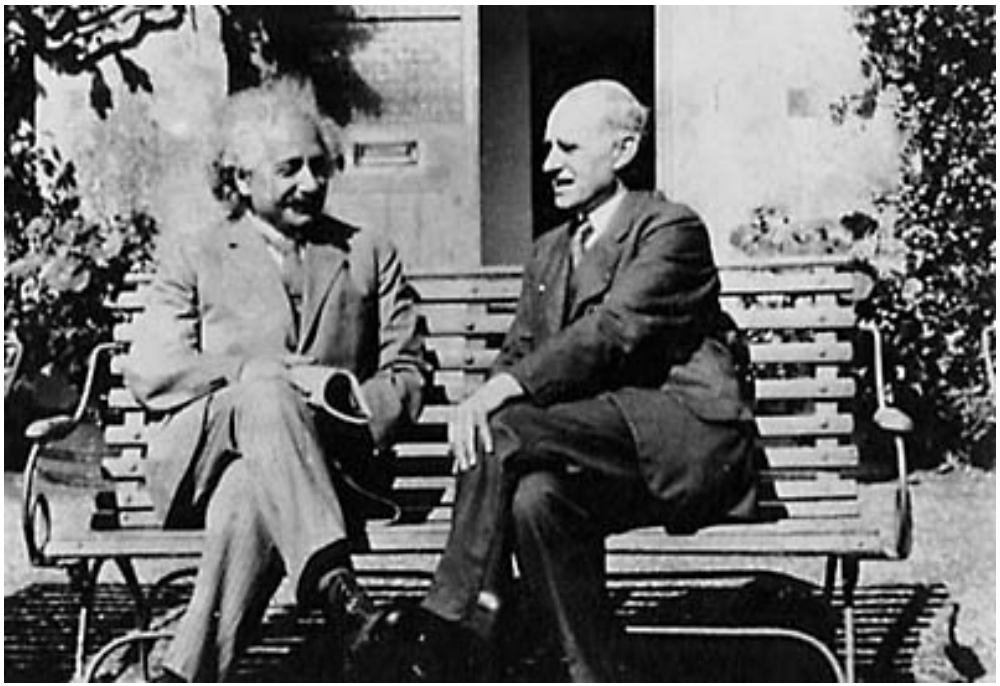
CPT Theorem

- Charge Conjugation
- Parity
- Time Reversal

Wolfgang Pauli

Einstein's Principle of Equivalence

- Acceleration + Special Relativity means space-time is curved
- Inertial mass equivalent to gravitational mass suggests gravity can be generated by acceleration
- Gravity should be relatable to space-time curvature



Disorder

- Ergotic Hypothesis
- Entropy
- Information
- Chaos
- Time’s arrow

Ludwig Boltzmann

Observations impacting Cosmology

- Olbers' paradox
- Hubble's expansion
- Residual black-body radiation
- Dark matter, galaxy voids
- Evolution of galaxies and stars
- Kaon decay as T-reversal violation
- Proton decay $>10^{32}$ yrs
- 6 leptons, 6 quark flavors, 3 colors of quarks
- Hulse and Taylor gravitational radiation
- Black hole behavior

Cosmology Models

- Einstein: G+ Λg=κT
- Schwarzschild, Kerr solutions
- Friedmann, Robinson, Walker universe (isotropic, homogeneous)
- Hawking semi-classical quantization
- DeSitter Inflation, post acceleration